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A DEA-based Malmquist Productivity Index for Analysing University Performance and Competitiveness

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ABSTRACT

Objective: To conduct a comparative analysis of university performance and competitiveness for leading Polish and Ukrainian universities using the constant returns to scale (CRS) results-oriented model and DEA-based Malmquist productivity index.

Research Design & Methods: Using the CRS results-oriented model and DEA-based Malmquist productivity index, an assessment of the efficiency of Polish and Ukrainian higher education institutions in 2019–2021 has been carried out. Sources of data include reports from university rectors, international educational rankings and data from the SciVal Scopus database. The use of input and output indicators, which characterise the didactic and research activities of universities and affect their efficiency, has been justified. Input indicators are the number of university teachers, total university costs calculated per employee, total university costs calculated per student, and output indicators including the number of graduates, the annual number of employee publications in Scopus indexed journals, and the number of citations of employee publications according to SciVal Scopus.

Findings: First, the productivity of some Polish and Ukrainian universities differ, as do the factors of the growth of that productivity. Second, more reputable universities (including benchmarking units) have less potential for productivity growth than less productive regional

universities. The relevance of the results obtained was guaranteed by the size of the group of universities analysed. That number was larger than the minimum for maintaining a sufficient number of degrees of freedom.

Implications/Recommendations: As a result of analysis with the application of performance--oriented CRS model and Malmquist index, it was found that large reputable universities have less potential for productivity growth (this applies to benchmarking units mainly in Poland). Ukrainian universities are not only more diversified in terms of indicator dynamics, but have greater reserves of productivity growth.

Contribution: The article contributes to the scientific literature on university performance and the evaluation of competitiveness. The use of the CRS model and Malmquist index in the analysis of university competitiveness enables better characterisation and evaluation of the input and output indicators, identify benchmarking units and productivity growth reserves.

Article type: original article.

Keywords: DEA, Malmquist index, universities, efficiency, competitiveness, international rankings.

JEL Classification: I23, O47.

1. Introduction

Increasing the efficiency and competitiveness of higher education institutions (HEIs) in modern conditions is essential for many socio-economic reasons: changing demographic trends and increased competition among universities for students, more restrictive financial constraints due to the impact of permanent crisis phenomena, increasing pressure on public entities due to these limitations, globalisation trends, and the permanent need to improve the performance of universities for increased competitiveness, achieve success and high positions in international educational rankings. This contributes to the growing interest in evaluation issues and the search for ways to improve the efficiency of university operations. On issues of comparative evaluation, it is interesting to use international experience in identifying ways to increase the efficiency of universities and the factors that can provide such an increase.

The quantitative nonparametric data envelopment analysis (DEA) method has been used quite extensively in evaluating the effectiveness of universities. Since the basic version of the DEA method, known as CCR (Charnes, Cooper & Rhodes, 1978), was proposed, it has been developed extensively. CCR assumes the occurrence of constant returns to scale (CRS) – that is, a linear dependence between outputs and inputs, and a modification of the DEA method allowing for the presence of variable returns to scale (VRS) (Banker, Charnes & Cooper, 1984). Following the authors' last names, the modification goes by the acronym BCC (Banker, Charnes,

Cooper). More than 4,000 articles have been written about DEA by some 2,500 authors from more than 50 countries (Emrouznejad, Parker & Tavares, 2008). The decision-making units used in DEA analyses have equally defined inputs and outputs. Focused on the performance of specific public functions, these units are mostly not profit-oriented. In assessing their performance, the efficiency of management with defined resources is measured without reference to financial coefficients only. This has led the DEA method to be widely used in the study of public sector units (Chalos & Cherian, 1995; Odeck, 2005; Nazarko *et al*., 2008).

The Malmquist index based on DEA (Färe *et al*., 1994; Chen & Ali, 2004; Johnes, 2006; Fu, Song & Guo, 2009) is used to measure productivity change over time. It can be decomposed into two parts, including for measuring technology change and efficiency change. Comparative studies of universities have employed the Malmquist index based on DEA to analyse universities in the EU (Parteka & Wolszczak-Derlacz, 2013; de la Torre, Gómez-Sancho & Perez-Esparrells, 2017), Switzerland (Bolli & Farsi, 2015), the United Kingdom (Johnes, 2006), and Australia (Worthington & Lee, 2008).

However, when it comes to the application of the DEA method, there are relatively few publications that link the issues of university efficiency and competitiveness. Some authors (Nazarko *et al*., 2008) point out that in comparative studies of the efficiency of the operation of public sector units, evaluation through the identification of benchmarks can be treated as a substitute for competitiveness and thus contribute to the efficient allocation of public funds, attention to the efficiency of implemented processes, improvement of the quality of services provided and improvement of the management of public institutions.

2. Methodology

An important element in this analysis of the Polish and Ukrainian higher education system is a comparison of the competitive positions of the countries' higher education institutions. It will enable us not only to understand their evolution but, more importantly, to define the prospects for changes in the higher education sector in Ukraine, especially in terms of greater integration with the European Union after the war, as the country begins to be rebuilt.

The Malmquist index, based on DEA, was used to analyse the change in productivity over time of the most competitive Polish and Ukrainian universities. The information limitations that arose during the data search were taken into account.

The purpose of the analysis using DEA will not be to identify the most competitive units on the scale of entire countries, but to determine which of the leader universities designated according to their position in international rankings perform better and which perform worse. This means that this study makes an *a priori* assumption that the universities being compared have a high level of competitive-

ness, and the purpose of the analyses will be to see how a given university relatively – that is, in relation to the other universities under study – manages to achieve a given level of performance, using the inputs it has. Effective universities will be identified, i.e. those that, compared to the others, use the smallest number of inputs to achieve a given result. To achieve this goal, the following steps were followed:

– select Polish and Ukrainian universities-leaders of international rankings,

– determine the inputs and outputs for DEA analysis taking into account the analysed factors of competitiveness of the HEIs,

– analyse indicators from reports issued by the rectors of Polish and Ukrainian universities-leaders of international rankings, indicators from SciVal Scopus database and The Times Higher Education World University Rankings,

– conduct a DEA analysis of inputs and outputs of the universities with the application of CRS-O models for selecting benchmarking units,

– analyse inputs and outputs with the application of the Malmquist index, based on DEA.

The CRS-O model was chosen for assessing the efficiency of Polish and Ukrainian higher education institutions for a couple of reasons. First, decision--making units operate under the same scale efficiency, meaning they all use inputs and outputs in the same proportion. Second, CRS-O is simpler and easier to interpret than VRS-O. It assumes that any deviations from efficiency are solely due to managerial decisions, technology, or other factors unrelated to scale efficiency.

The Malmquist productivity change index is defined as the geometric mean of the productivity change rates in period t and $t + 1$. In the results-oriented (M_0) model, it is calculated according to the following formula (Färe *et al*., 1994):

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \right) \cdot \left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right) \right]^{1/2}. \quad (1)$$

$M_0 > 1$ indicates an increase in productivity, $M_0 < 1$ indicates a decrease in productivity, and $M_0 = 1$ indicates no change in productivity from time t to $t + 1$.

The Malmquist index can be decomposed into two components (Färe, Grosskopf & Weber, 1989; Färe *et al*., 1992):

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \right) \cdot \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right) \cdot \left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right) \right]^{1/2}. \quad (2)$$

EC is the efficiency change index. This index measures the change in technical efficiency over two periods (i.e., whether the unit is approaching its efficiency limit over time):

$$EC = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}. \quad (3)$$

TC is the index of technology change in two periods (i.e., the frontier moves over time):

$$TC = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right) \cdot \left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right) \right]^{1/2}. \quad (4)$$

When these indices have a value higher than one, a change for the better has occurred – that is, productivity has risen.

3. Competitiveness, Efficiency and International Education Rankings: How to Identify the Most Competitive Universities?

Ukraine, like several other post-Soviet economies, at the beginning of the transition had a relatively high share of population with higher education and a high enrolment rate. This has not changed significantly. Currently, the gross enrolment rate in Ukraine is 83% (compared to 69% in Poland, World Bank, 2019b). This is one of the highest indicators in Europe. At the same time, Ukraine spends a lot on education (5.4% of GDP compared to 4.6% in Poland, World Bank, 2019a). However, given Ukraine's relatively low GDP, these expenditures are *de facto* lower than in EU countries. Such high enrolment rates prompt questions about the graduates' professional paths. The analysis of the structure of Ukrainian GDP, as well as the place of Ukraine in the global value-added chain, does not indicate that there is an above-average demand for the labour with higher education in this economy. One therefore wonders how effective expenditures on education actually are.

Despite the two countries' differing general economic situations and financial inputs, Ukraine and Poland had roughly similar positions in international educational rankings in higher education prior to the war. For example, in the 2020 Universitas 21 Ranking (Universitas 21, 2020), Poland ranked 32nd and Ukraine 36th. If, however, the results are adjusted for a country's level of wealth, Poland is ranked 29th and Ukraine 14th – well above expectations. In 2020, in the evaluation of the resources component (including public expenditures, general expenditures, university expenditures on research and development) Poland ranked 31st in the ranking, Ukraine 27th; in the assessment of the environment component (quantified presentation of the political and regulatory environment, the degree of balance of the student and teacher population structure by gender) – Poland ranked 17th, Ukraine 39th; in the evaluation of the communication component (which includes interaction with business and industry, number of foreign students, academic publications prepared with foreign partners, and Internet communication) Poland ranked 37th and Ukraine 38th; in the results component (including research and its impact, availability of world-class universities, workforce qualifications) Poland ranked 31st, and Ukraine 42nd. For number of papers published, Poland ranked 18th and

Ukraine 45th. At the same time, Poland's rank for the average impact factor for publications was 32nd, while Ukraine ranked 50th.

Table 1. Ukrainian and Polish University – Leaders of International Education Rankings in 2021

University	Ranking		
	Web of Universities	The QS World University Rankings	The Times Higher Education World University Rankings
Ukrainian universities			
National Taras Shevchenko University of Kyiv (KNU)	1 (1,162)	2 (601–650)	4–9 (1,001+)
Sumy State University (SumDU)	3 (1,796)	4–5 (701–750)	1–2 (501–600)
National Technical University of Ukraine Kyiv Polytechnic Institute (NTUU KPI)	2 (1,597)	4–5 (701–750)	4–9 (1,001+)
Kharkiv National University VN Karazin (KhNU)	4 (2,380)	1 (477)	4–9 (1,001+)
National Technical University Kharkiv Polytechnical Institute (NTU KhPI)	5 (2,542)	3 (651–700)	4–9 (1,001+)
Kharkiv National University of Radio Electronics (NURE)	8 (2,667)	–	3 (801–1,000)
National Aerospace University Kharkiv Aviation Institute (NAU KhAI)	6 (2,578)	–	–
Lviv Polytechnic National University (LPNU)	10 (2,923)	6 (801–1,000)	1–2 (501–600)
National University of Life and Environmental Sciences of Ukraine (NULES)	7 (2,605)	–	–
Ivan Franko National University of Lviv (IFNUL)	13 (3,226)	–	4–9 (1,001+)
Polish universities			
Jagiellonian University (UJ)	1 (321)	2 (326)	1 (501–600)
University of Warsaw (UW)	2 (321)	1 (321)	3 (801–1,000)
Warsaw University of Technology (PW)	4 (512)	3 (511–520)	4–19 (1,000+)
AGH University of Science & Technology (AGH)	3 (429)	–	4–19 (1,000+)
Poznan University of Technology (PP)	7 (723)	–	–
Adam Mickiewicz University (UAM)	5 (557)	–	4–19 (1,000+)
Medical University of Warsaw (WUM)	14 (990)	–	2 (801–1,000)
Nicolaus Copernicus University (UMK)	6 (661)	–	4–19 (1,000+)
University of Wroclaw (UWr)	8 (754)	–	4–19 (1,000+)
Silesian University of Technology in Gliwice (POLSL)	9 (842)	–	4–19 (1,000+)

Source: Web of Universities (Webometrics.info, 2021a, 2021b), The QS World University Rankings (Top Universities, 2021), The Times Higher Education World University Rankings (Times Higher Education, 2021a, 2021b).

The competitiveness of universities is strictly related to their efficiency: high efficiency leads to better outcomes, and thus a university with high efficiency represents itself respectably in international and national rankings. The most competitive Polish and Ukrainian universities in this study are determined with the use of international educational rankings Web of Universities, The QS World University Rankings, and The Times Higher Education World University Rankings. These rankings were chosen because the largest number of Polish and Ukrainian universities are presented in these rankings. Unlike most university rankings (The QS World University Rankings, The Times Higher Education World University Rankings, Academic Ranking of World Universities and others), there are no range places in the Web of Universities rankings, so the position of each university is precisely determined. So that their progress could be checked, I also analysed, in 2019–2020, the list of the most competitive universities designated in 2021. The top 10 universities were determined by calculating the geometric mean of the universities' positions in these rankings (Table 1).

In this study, 60 university rector reports (30 Ukrainian and 30 Polish) for 2019–2021 were analysed. The content and number of indicators used in the reports from Ukrainian universities, despite certain aspects that are required for inclusion in these reports, differ greatly. According to the results of the analysis, the most useful information and indicators were in the reports from the Rector of National Taras Shevchenko University of Kyiv. The scope and content of the reports, in addition to the issues determined by the legal regulations on the implementation of the rectors' employment agreements, also related to the scale of the university and the specifics of the prevailing corporate culture. As for the Polish universities, the reports from the University of Warsaw, Jagiellonian University, and Adam Mickiewicz University contain the most information. The number of indicators and their level of detailing in the various rectors' reports also varies.

4. Input and Output Indicators Used in the Analysis with DEA Method

In conducting a DEA analysis it is essential to determine the inputs and outputs of universities that will be used in the evaluation and the size of the group of universities analysed in the study. In most of the studies, both input and output ratios characterise teaching and research activities. This is primarily due to the definition of the concept of technical efficiency of universities as the ratio of the results of university activities (number of graduates or publications) to inputs (number of people employed, revenues).

In studies conducted for Polish universities using DEA (e.g., Wolszczak-Derlacz, 2015), the following indicators are used: the value of the university's revenue,

the number of researchers and students, the results of scientific activity (number of publications), and teaching activity (number of graduates).

In a more extended list of indicators (e.g., Wolszczak-Derlacz, 2018), the following can also be applied to assess the technical efficiency of the activities of higher education institutions: number of employees (academic staff, non-academic staff by grade and position); number of teaching hours performed by academic staff; financial resources (the value of revenue by source), costs by form of incurrence, assets, premises conditions (e.g., laboratory space). Outputs include: number of publications by employees with the affiliation of the university, citation rates, impact indicators, number of degrees and titles awarded; number of graduates (number of bachelor's, master's degrees); number of students (e.g., advancing to higher years, obtaining a given number of ECTS credits); results from tests and examinations, e.g., results from graduation examinations, grades on diplomas, patents, industrial designs, numbers and value of contracts with external entities; amount of funds obtained for scientific activities from external sources, value of research services sold.

In some studies of the effectiveness of Polish higher education institutions, only indicators of didactic or research activities are analysed. For instance, in a study of the effectiveness of didactic activities of higher education institutions (Brzezicki, 2017), it was pointed out that, depending on the empirical model chosen, either the total number of academic teachers (full-time and part-time) or the total value of didactic revenue could be included as inputs, while outputs could include either the total number of students (full-time and part-time) including foreigners or the total number of graduates (full-time and part-time) including foreigners.

Table 2. Input-output Indicators in the DEA Model

Indicator	Description of the Indicator
Input indicators	
The number of university teachers (x_1)	One of the variables that characterises the human resource potential of a university. It has a direct impact on publication activity rates. That the majority of employees are engaged in research and publication activity is an important condition for working at a university. The source of empirical data is The Times Higher Education World University Rankings and reports of rectors of Polish and Ukrainian universities
Total university costs calculated per employee, in euro (x_2)	Measures the expenditure on teaching and research activities by universities. The use of a cost indicator calculated per employee makes it possible to compare universities of different scales. Due to gaps in the information available, a more appropriate indicator of total costs of scientific activity was not used in the study. Data from Poland and Ukraine, expressed in national currency, were reduced to a common unit – the euro. Data are sourced from rector reports of the higher education institutions

Table 2 cnt'd

Indicator	Description of the Indicator
Total university costs calculated per student, in euro (x_3)	Reflects expenditures on teaching and research activities. For research purposes, it would also be worthwhile to use the indicator of total costs of teaching-only activities for the analysis, but such data is not available for every university. While this lack of data more characterises Ukrainian HEIs, data is not presented in the rectors' reports of all Polish HEIs. To ensure comparability between HEIs of different scales, the cost indicator is calculated per student
Output indicators	
The annual number of employee publications in Scopus indexed journals (y_1)	An indicator worth including in the evaluation of scientific performance. It characterises not only the publication activity of scientists with a university's affiliation, but also the quality of the publications. The data source is the SciVal Scopus database, which currently presents information on the number of publications between 2012 and 2021
The number of citations of employee publications according to SciVal Scopus (y_2)	Can be used to assess the quality of scientific publications. It was taken from the SciVal Scopus database and is available for Polish and Ukrainian universities for the 2012–2021 period. The citation index will be used for the three study periods: 2012–2019, 2012–2020 and 2012–2021
The number of graduates (y_3)	One of the main quantitative indicators characterising the didactic performance and scale of HEIs. It does not take into account the quality of education. However, quality can be characterised – for example, by the brand of university alumni graduated from

Source: the author.

Table 2 provides a brief description of all the variables used in this study for Polish and Ukrainian universities follows. It also identifies the source of the empirical data and justifies their selection for the model.

To calculate the minimum size of the group of objects analysed in the study using the DEA method, in order for there to be a sufficient number of degrees of freedom, the number of universities (denoted by n) should be at least (Domagała, 2009, p. 146):

$$n_{\min} = \max\{m \cdot s; 3 \cdot (m + s)\}, \tag{5}$$

where: m is the number of inputs and s is the number of outputs.

This condition is treated as a so-called strong recommendation, but not as a condition for the solvability of DEA models. It arose as a result of simulation studies and should be treated as a certain practical rule, which they call the "rule of thumb" (Domagała, 2009, p. 146). In this study, the number of inputs and outputs is 3, so the number of universities studied can be in such a range: (9; 18). The actual number is higher and represents 10 Polish and 10 Ukrainian HEIs, the indicators of which are analysed for the years 2019–2021.

Indicators of inputs and outputs of Ukrainian and Polish universities-leaders of international education rankings in 2019–2021 are presented in Tables 3 and 4.

Table 3. Input Indicators of Ukrainian and Polish Universities-leaders of International Education Rankings in 2019–2021

University	Number of University Teachers			Total University Costs Calculated per Employee, in Euro			Total University Costs Calculated per Student, in Euro		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
Ukrainian universities									
KNU	2,944	2,974	2,707	26,545.2	23,169.8	30,207.9	3,488.8	2,966.4	3,452.2
SumDU	902	854	815	23,808.3	25,985.6	32,033.5	2,334.3	2,388.0	2,810.9
NTUU KPI	2,249	2,206	2,063	28,169.6	30,205.8	36,210.5	3,274.6	3,249.5	3,545.1
KhNU	1,755	1,804	1,839	12,985.4	13,842.3	15,236.2	1,418.2	1,459.5	1,637.3
NTU KhPI	1,673	1,597	1,518	12,131.3	13,022.4	15,371.1	1,490.9	1,550.3	1,921.4
NURE	773	765	635	15,641.3	14,200.3	21,939.3	1,386.5	1,192.3	1,728.9
NAU KhAI	684	692	622	30,730.3	29,447.1	32,861.7	3,127.0	3,294.6	3,251.1
LPNU	2,047	2,091	2,031	14,316.8	14,250.9	20,917.5	1,301.5	1,382.1	1,945.2
NULES	1,144	1,337	1,151	21,833.6	19,077.8	25,837.0	1,648.3	1,583.6	1,840.0
IFNUL	1,897	1,886	2,124	11,738.2	14,275.8	15,706.8	1,222.7	1,660.0	1,789.2
Polish universities									
UJ	2,984	3,035	3,068	76,561.6	67,899.6	68,405.8	5,422.6	5,074.7	5,515.0
UW	3,834	3,894	3,974	96,322.0	90,670.3	92,074.5	7,422.8	6,993.7	8,850.2
PW	2,429	2,473	2,492	84,404.9	78,395.3	79,923.1	6,473.2	6,525.7	8,170.7
AGH	2,216	2,093	2,100	85,198.7	82,940.6	90,992.9	6,042.5	6,065.5	7,659.0
PP	1,429	1,326	1,332	57,124.2	59,783.1	60,727.1	6,779.4	6,683.4	6,909.4
UAM	2,733	2,832	2,842	60,762.0	57,643.6	61,689.1	4,413.0	4,337.7	5,076.7
WUM	1,798	1,816	1,885	51,542.4	51,204.3	50,205.0	9,385.6	9,296.7	9,357.9
UMK	2,324	2,363	1,946	52,092.6	50,810.9	61,900.3	5,114.6	5,351.0	5,477.9
UWr	1,597	1,604	1,595	71,288.7	72,542.2	74,803.6	4,853.3	5,034.1	5,381.6
POLSL	1,641	1,638	1,630	68,705.9	69,214.3	73,151.1	6,227.0	5,491.3	6,664.2

Source: The Times Higher Education World University Rankings 2019–2021, reports of rectors of Ukrainian and Polish universities.

In the structure of the total costs of Ukrainian HEIs, the costs of teaching combine those of the general and special fund under the expenditure item "Training of personnel by HEIs and ensuring the functioning of their practice bases", and the costs of scientific activity under the item "Scientific and scientific-technical activities of HEIs and scientific institutions". The majority of Ukrainian HEIs, shown

in Table 3, are large HEIs with more than 15,000 students (the HEIs under analysis here have an average of 15,299 students). The average number of students per one employee in 2019–2021 was 9.98, while the average share of foreign students was 7.3%. The total costs in the calculation per student at the the most competitive universities surveyed are much higher than, for example, the average educational costs per student (2,178 euro/year in the years 2019–2021), which in the academic year 2020/2021 in Ukraine accounted for 1,479.6 euro/year.

Table 4. Output Indicators of Ukrainian and Polish Universities-leaders of International Education Rankings in 2019–2021

University	The Number of Graduates			The Annual Number of Employee Publications in Scopus Indexed Journals			The Number of Citations of Employee Publications According to SciVal Scopus		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
Ukrainian universities									
KNU	3,767	3,296	2,870	1,556	1,778	1,781	80,196	88,790	93,756
SumDU	468	441	437	400	575	617	23,787	28,027	31,131
NTUU KPI	2,146	1,871	2,190	898	1,007	1,012	25,433	29,433	31,788
KhNU	1,106	1,153	1,280	860	904	941	32,092	35,167	37,180
NTU KhPI	2,085	1,617	1,555	522	544	582	13,438	15,151	16,214
NURE	1,595	930	823	452	327	389	9,202	10,440	11,215
NAU KhAI	786	663	464	219	268	247	8,319	9,231	10,069
LPNU	2,092	2,157	2,935	1,102	657	1,323	34,084	39,451	42,872
NULES	2,643	2,275	2,341	351	513	592	7,634	9,772	11,282
IFNUL	3,931	2,488	2,922	567	657	620	20,565	22,879	24,106
Polish universities									
UJ	7,946	7,773	8,146	3,966	4,248	4,725	609,759	658,962	687,945
UW	9,027	8,933	9,109	3,214	3,401	3,448	454,457	493,033	512,859
PW	6,321	5,432	5,723	2,397	2,396	2,490	246,975	268,986	280,027
AGH	8,313	6,571	6,120	2,597	2,508	2,699	283,894	307,633	323,283
PP	4,715	4,492	4,602	1,198	1,300	1,237	104,421	114,741	122,530
UAM	6,873	7,270	7,040	1,868	1,925	2,024	196,479	213,812	225,066
WUM	2,121	2,095	2,129	1,753	1,933	2,424	213,508	236,760	253,985
UMK	6,102	5,085	4,847	1,407	1,713	2,056	138,010	157,093	167,859
UWr	5,758	5,659	5,807	1,320	1,427	1,495	140,714	151,828	158,527
POLSL	5,094	4,735	4,647	1,840	1,725	1,813	119,375	134,200	145,167

Source: The Times Higher Education World University Rankings 2019–2021, SciVal Scopus database data, reports of rectors of Ukrainian and Polish higher education institutions, GUS (2022).

Most of the Polish universities are large (the average number of students is 26,728), with the average number of students per employee in 2019–2021 standing at 11.96 (19.8% more than in Ukrainian universities). Foreign students comprise 4.8% of the student body. The total costs in the calculation per student in the most competitive universities in the period under review are much higher (6,402 euro/year) than the average educational costs per student in the country, which in the 2020/2021 academic year in Poland accounted for 5,355.5 eurou/year.

The publication activity indicators of Ukrainian universities-leaders of international educational rankings are lower than those of Poland. Employees publish less in Scopus-listed journals (on average, 742 for Ukrainian univeristies *versus* 2,285 for Polish ones), and a much lower number of citations of publications (according to SciVal Scopus, 28,423 in the years 2012–2019 for Ukrainian universities *versus* 270,730 for Polish universities).

5. Is the Productivity of the Benchmarking Units Increasing Faster?

As a result of DEA analysis with the application of CRS models and input-output indicators that characterise the teaching and research activities of Polish and Ukrainian universities, benchmarking units were determined (Table 5).

Table 5. Results of the DEA Analysis Conducted Using CRS Models for Ukrainian and Polish Universities in 2019–2021

University	2019	2020	2021	Comments
Ukrainian universities				
KNU	1.000	1.000	1.000	Benchmarking unit
SumDU	1.033	1.000	1.000	Benchmarking unit (reserves +1.1%)
NTUU KPI	1.393	1.308	1.335	There are reserves of efficiency increases, on average +34.5%
KhNU	1.059	1.000	1.000	Benchmarking unit (reserves +2.0%)
NTU KhPI	1.321	1.265	1.422	There are reserves of efficiency increases, on average +33.6%
NURE	1.000	1.152	1.074	There are reserves of efficiency increases, on average +7.5%
NAU KhAI	1.509	1.361	1.667	There are reserves of efficiency increases, on average +51.2%
LPNU	1.000	1.000	1.000	Benchmarking unit
NULES	1.000	1.000	1.000	Benchmarking unit
IFNUL	1.000	1.000	1.000	Benchmarking unit

Table 5 cnt'd

University	2019	2020	2021	Comments
Polish universities				
UJ	1.000	1.000	1.000	Benchmarking unit
UW	1.149	1.151	1.174	There are reserves of efficiency increases, on average +15.8%
PW	1.258	1.315	1.316	There are reserves of efficiency increases, on average +29.6%
AGH	1.000	1.000	1.031	Benchmarking unit (reserves +1.0%)
PP	1.137	1.006	1.039	There are reserves of efficiency increases, on average +6.1%
UAM	1.000	1.000	1.043	Benchmarking unit (reserves +1.4%)
WUM	1.363	1.315	1.198	There are reserves of efficiency increases, on average +29.2%
UMK	1.000	1.203	1.219	There are reserves of efficiency increases, on average +14.1%
UWr	1.040	1.000	1.000	Benchmarking unit (reserves +1.3%)
POLSL	1.092	1.102	1.108	There are reserves of efficiency increases, on average +10.1%

Source: the author.

As a result of the DEA analysis, four benchmarking units were selected for Ukrainian universities with an efficiency index of 1.0 and two universities with very small efficiency growth reserves. For Polish universities in the period under review, the benchmarking unit is Jagiellonian University. Another three universities (AGH University of Science and Technology, Adam Mickiewicz University in Poznan, University of Wroclaw) have very small reserves of efficiency growth. On average, the efficiency of the Ukrainian universities studied can be increased by 13.0%, and the Polish ones by 10.9%. This means the Polish universities are more technically efficient than Ukrainian ones. Table 6 shows the results of the DEA analysis in R with the application of the Malmquist index, which targeted results using the CRS model.

The results show that the annual productivity growth for Ukrainian universities in 2020/2019 averaged 11.7%, while in 2021/2020 the reduction came in at 2.9%. Such a large change is due to the falling rate of technological progress. For Polish universities, the reduced productivity in 2020/2019 averaged 1.4%, while in 2021/2020 it was +1.5%. In 2020–2021, the decrease in productivity was partly attributable to the impact of the COVID-19 pandemic, which has led to a switch

to distance learning in many universities and long-term educational losses for the educational systems of many countries.

Table 6. Results of DEA Analysis with Application of Malmquist Index for Ukrainian and Polish Universities in 2019–2021

University	2020/2019			2021/2020		
	MPI	TC	EC	MPI	TC	EC
Ukrainian universities						
KNU	0.9034594	0.9034594	1.0000000	1.0793780	1.0793780	1.0000000
SumDU	0.7919759	0.8180762	0.9680956	0.8927729	0.8927729	1.0000000
NTUU KPI	0.9257438	0.9853598	0.9394983	0.8943993	0.8768872	1.0199708
KhNU	0.9765926	1.0346257	0.9439090	1.0581683	1.0581683	1.0000000
NTU KhPI	1.1522060	1.2031554	0.9576535	1.0711057	0.9531288	1.1237786
NURE	1.4212119	1.2337473	1.1519473	0.7950779	0.8531480	0.9319343
NAU KhAI	1.0040678	1.1130255	0.9021067	1.0754687	0.8780219	1.2248769
LPNU	1.1287767	1.1287767	1.0000000	0.9851570	0.9851570	1.0000000
NULES	1.2617942	1.2617942	1.0000000	0.9015151	0.9015151	1.0000000
IFNUL	1.6004716	1.6004716	1.0000000	0.9615963	0.9615963	1.0000000
Polish universities						
UJ	0.9710112	0.9710112	1.0000000	0.9068051	0.9068051	1.0000000
UW	1.0066776	0.9869611	1.0199769	0.9769474	0.9753796	1.0016074
PW	0.9620124	0.9608952	1.0011627	1.0891855	1.0418630	1.0454210
AGH	1.0063715	0.9757196	1.0314147	1.0952684	1.0952684	1.0000000
PP	1.0007285	0.9689844	1.0327602	0.9858730	1.1145663	0.8845351
UAM	1.1173965	1.0708293	1.0434871	0.9293164	0.9293164	1.0000000
WUM	0.8277415	0.9088231	0.9107840	0.9159594	0.9495724	0.9646020
UMK	0.9989369	0.9861455	1.0129711	1.1530935	0.9582016	1.2033934
UWr	0.9867733	0.9867733	1.0000000	1.0306801	1.0723713	0.9611224
POLSL	0.9876691	0.9827367	1.0050190	1.0691428	1.0589286	1.0096458

Notes: MPI – Malmquist productivity index, TC – technology change index, EC – efficiency change index.

Source: the author's own calculations.

2022 was an extremely difficult year for Ukrainian universities – hopes for the end of the COVID-19 pandemic and the transition to normal work remained unrealised. Worse still, according to the Ministry of Education and Science of Ukraine (2024), more than 70 universities have been damaged during the full-scale war with Russia (more than 10 were completely destroyed). Universities in the Kharkiv region

suffered the most (1 destroyed, 29 damaged); Donetsk (3 destroyed, 10 damaged), and Mykolaiv region (5 damaged). The priority for Ukrainian universities today is therefore to ensure safety during the educational process, gradually rebuild damaged buildings, and protect students and staff as much as possible.

Since the beginning of the war, professors emigrating has also been a significant challenge for Ukrainian universities. In 2022 more than 4,800 university teachers went abroad – 4.9% of the total number in Ukraine (Ministry of Education and Science of Ukraine, 2022, p. 199). Some have found jobs or internships under programmes that support Ukrainian scientists in continuing their research. This large-scale emigration could take an outsize toll on the Ukrainian economy, while attracting young, highly skilled professionals will be a boon for the EU economy.

6. Conclusions

As a result of analysis with the application of performance-oriented CRS model and Malmquist index, it was found that large, reputable universities have less potential for productivity growth (this applies to benchmarking units mainly in Poland). Ukrainian universities are not only more diversified in terms of indicator dynamics, but have greater reserves of productivity growth. However, poor funding significantly limits their growth opportunities. The increase in technical efficiency may primarily be associated with improving the quality of scientific articles and increasing the internationalisation of scientific research. Publishing more in English, and using the language more widely on campuses would be a large step in this direction. It would also boost their competitiveness and improve their position in international educational rankings.

Assessing the war's toll on the higher education system, educational losses due to the decline in the quality of education, and various aspects of effective post-war reconstruction of the educational system are all important areas for further research. Doing so would help save the research and educational potential of Ukrainian universities while increasing their competitiveness in the educational services market.

Conflict of Interest

The author declares no conflict of interest.

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